Comparisons of Sub-Diurnal Wind Vector Variability Near Convection from Models and the Constellation of Scatterometers and Radiometers

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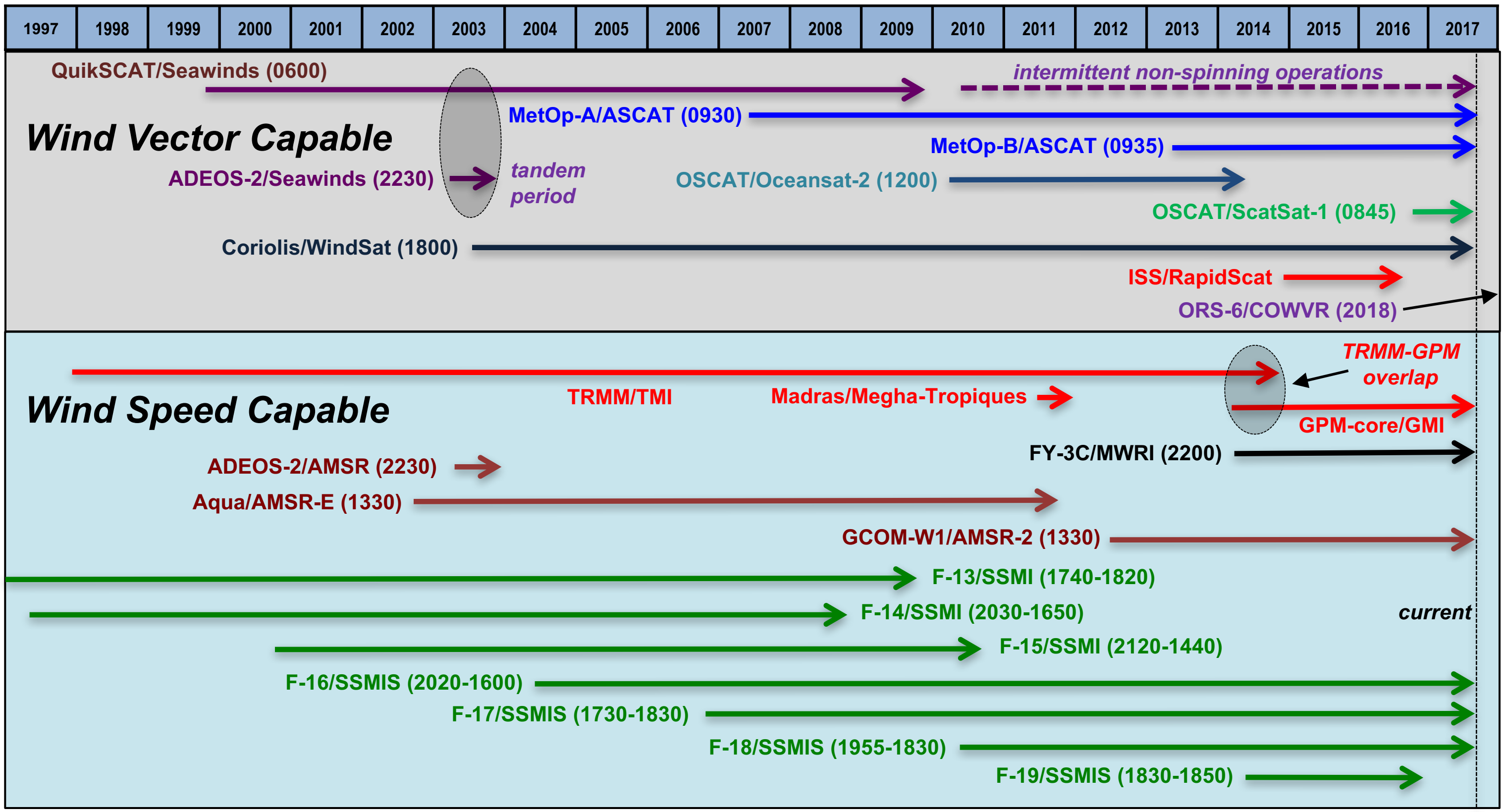
Ocean Winds Diurnal Cycle Workshop
30 October 2017, La Jolla, CA

Current and Near-Future Constellation of Scatterometers, Radiometers and Microwave Polarimeters



F-20 no plans to fly
GMI-2 looking for a partner, last I heard
AMSR-3 maybe….
COWVR on ORS-6 early next year (like WindSat)
GPM-core has sufficient fuel for into the 2030s

Rationale

A number of studies have focused on the 2003 QuikScat + SeaWinds period (tandem period) to examine diurnal winds (diurnal= first harmonic of the daily cycle).

Findings are tied to the particular meteorology of this 7-month period. May not matter for some studies, but will for others.

Longterm collection of wind radiometers may provide additional observations to study diurnal wind variability over the longer term, e.g.

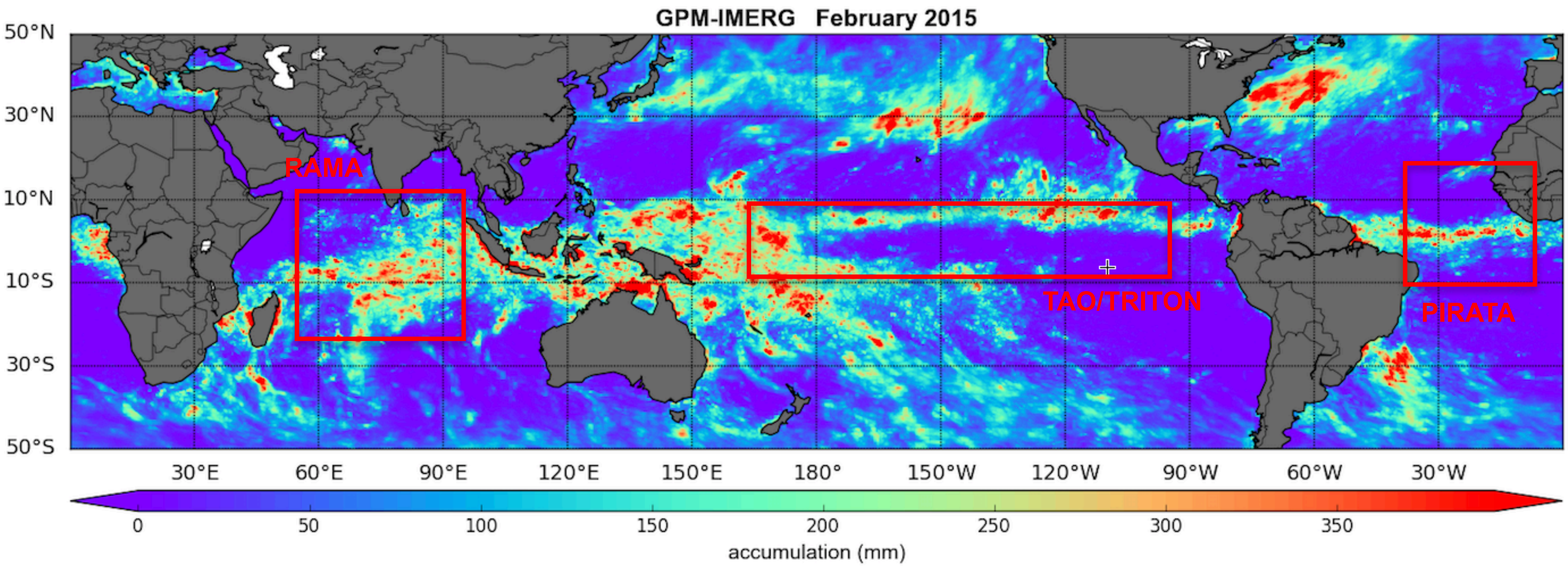
1) Better understandings of the mechanisms that influence joint diurnal variability of ocean winds and oceanic convection, and how the structure of the convection comes into play

2) Provide observations to better assess why models agree fairly well in overall speed/direction, but less so in diurnal variability

3) Extend coverage more globally outside of moored arrays, which have temporal gaps in coverage

Extending the Diurnal Winds Analysis to Cover More El Nino and intraseason oscillation events

Monthly Precipitation   February 2015



Extending the Diurnal Winds Analysis to Cover More El Nino and intraseason oscillation events

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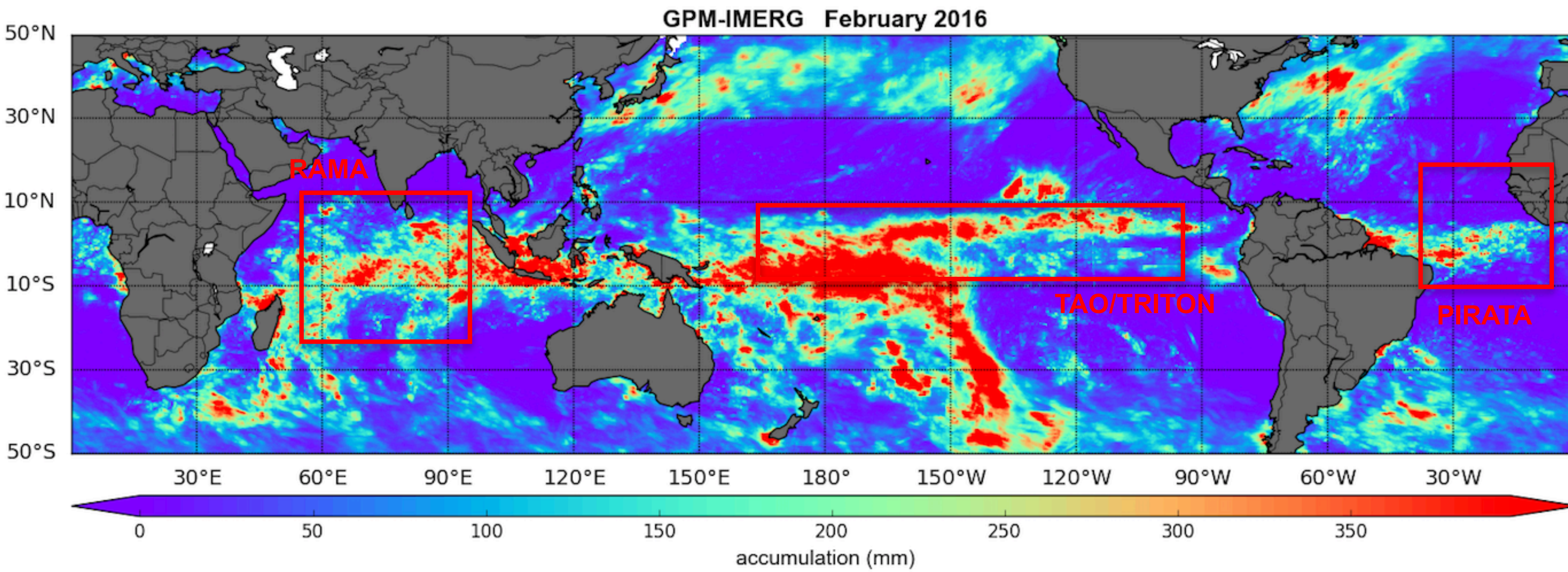


Principle (from 2017 OVWST earlier this year)

The speed-only radiometers provide additional degrees of freedom (when an insufficient number of scatterometer observations are available on any given day) to examine diurnal wind variability beyond the brief tandem mission period.

$$
\begin{pmatrix} u_1 \\ v_1 \\ \vdots \\ u_n \\ v_n \end{pmatrix}
=
\begin{pmatrix}
\overbrace{a_0 + a_1\cos(2\pi t_1/24) + a_2\sin(2\pi t_1/24)}^{\textbf{daily}} + \overbrace{a_3\cos(4\pi t_1/24) + a_4\sin(4\pi t_1/24)}^{\textbf{sub-daily}} \\
b_0 + b_1\cos(2\pi t_1/24) + b_2\sin(2\pi t_1/24) + b_3\cos(4\pi t_1/24) + b_4\sin(4\pi t_1/24) \\
\vdots \qquad\qquad \vdots \qquad\qquad \vdots \qquad\qquad \vdots \\
a_0 + a_1\cos(2\pi t_n/24) + a_2\sin(2\pi t_n/24) + a_3\cos(4\pi t_n/24) + a_4\sin(4\pi t_n/24) \\
b_0 + b_1\cos(2\pi t_n/24) + b_2\sin(2\pi t_n/24) + b_3\cos(4\pi t_n/24) + b_4\sin(4\pi t_n/24)
\end{pmatrix}
$$

$$\vec{x} = \left(a_0\ a_1\ a_2\ a_3\ a_4\right)^T$$

$$\vec{y} = \left(b_0\ b_1\ b_2\ b_3\ b_4\right)^T$$

Estimate 6 terms (diurnal only) or 10 terms (diurnal + semi-diurnal)

Principle (from 2017 OVWST earlier this year)

For the speed-only (w) radiometers, since the relation between *w* and the *u* and *v* components is non-linear, hypothetical vectors are created by varying the directions one degree at a time (e.g., for one radiometer):

$$u_{n+1} = w\cos(\theta) = a_0 + a_1\cos(2\pi t_1/24) + a_2\sin(2\pi t_1/24) + a_3\cos(4\pi t_1/24) + a_4\cos(4\pi t_1/24)$$

$$v_{n+1} = w\sin(\theta) = b_0 + b_1\cos(2\pi t_1/24) + b_2\sin(2\pi t_1/24) + b_3\cos(4\pi t_1/24) + b_4\cos(4\pi t_1/24)$$

$$E(\theta) = \min\left(\sum_{i=1}^{n}\left(u_{n+1} - u_i\right)^2 + \left(v_{n+1} - v_i\right)^2\right)$$

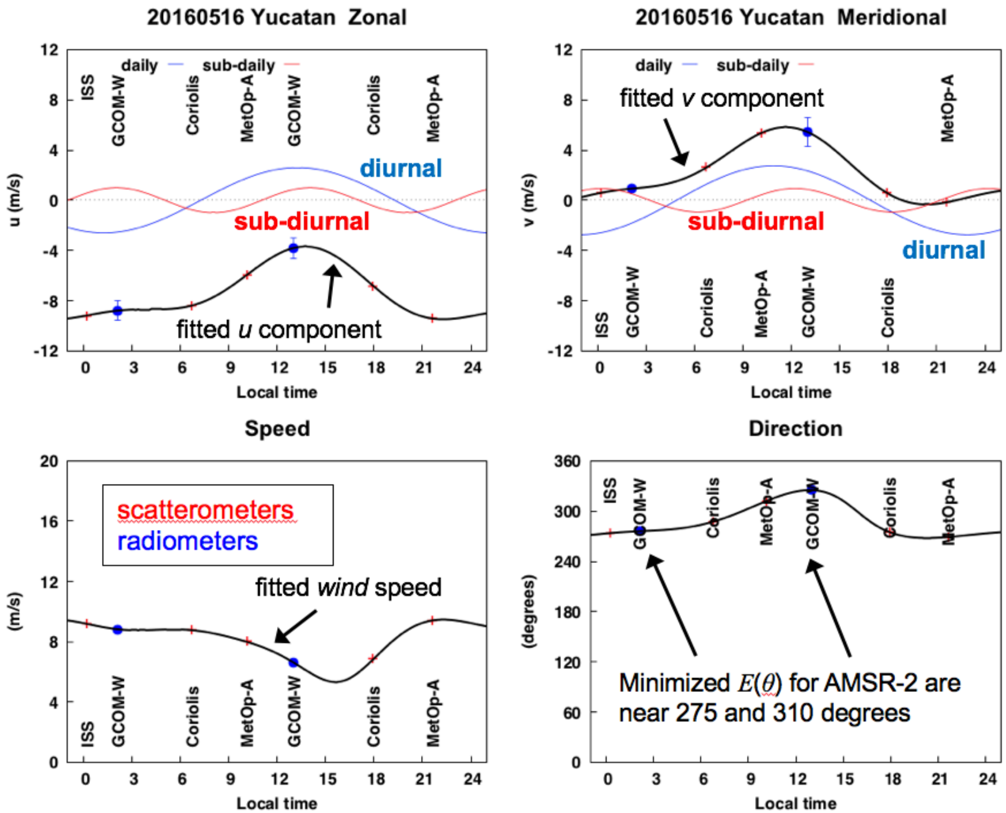
Locate the directions θ that best agree with the observed vectors.

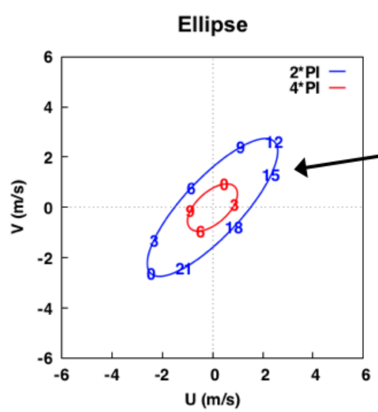
In either the diurnal-only or semidiurnal case, these expressions can be expressed in matrix form, where D_u and D_v are diagonal matrices with the variance of the u and v observations.

$$\hat{\vec{x}} = \left(A^T D_u^{-1} A\right)^{-1} A^T D_u^{-1} U$$

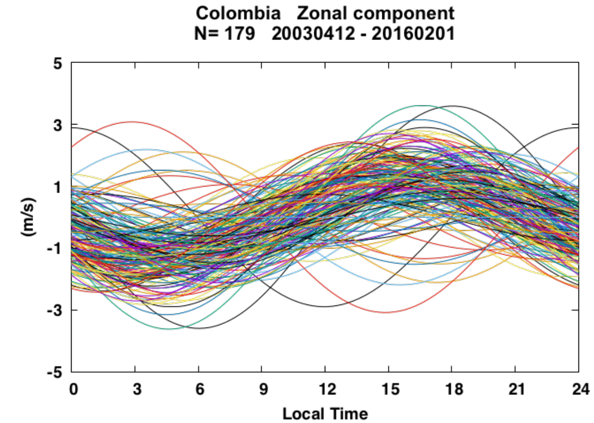
$$\hat{\vec{y}} = \left(A^T D_v^{-1} A\right)^{-1} A^T D_v^{-1} V$$

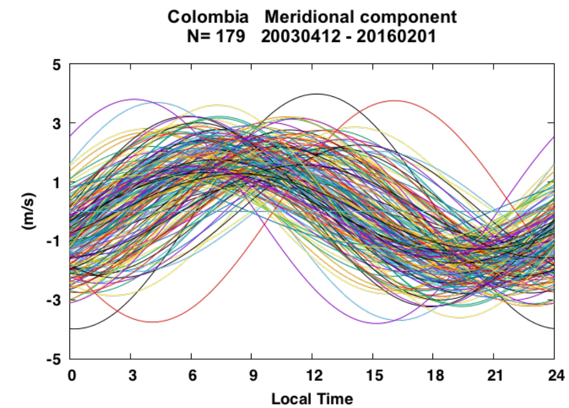
Example (16 May 2016)
Offshore of Yucatan coast





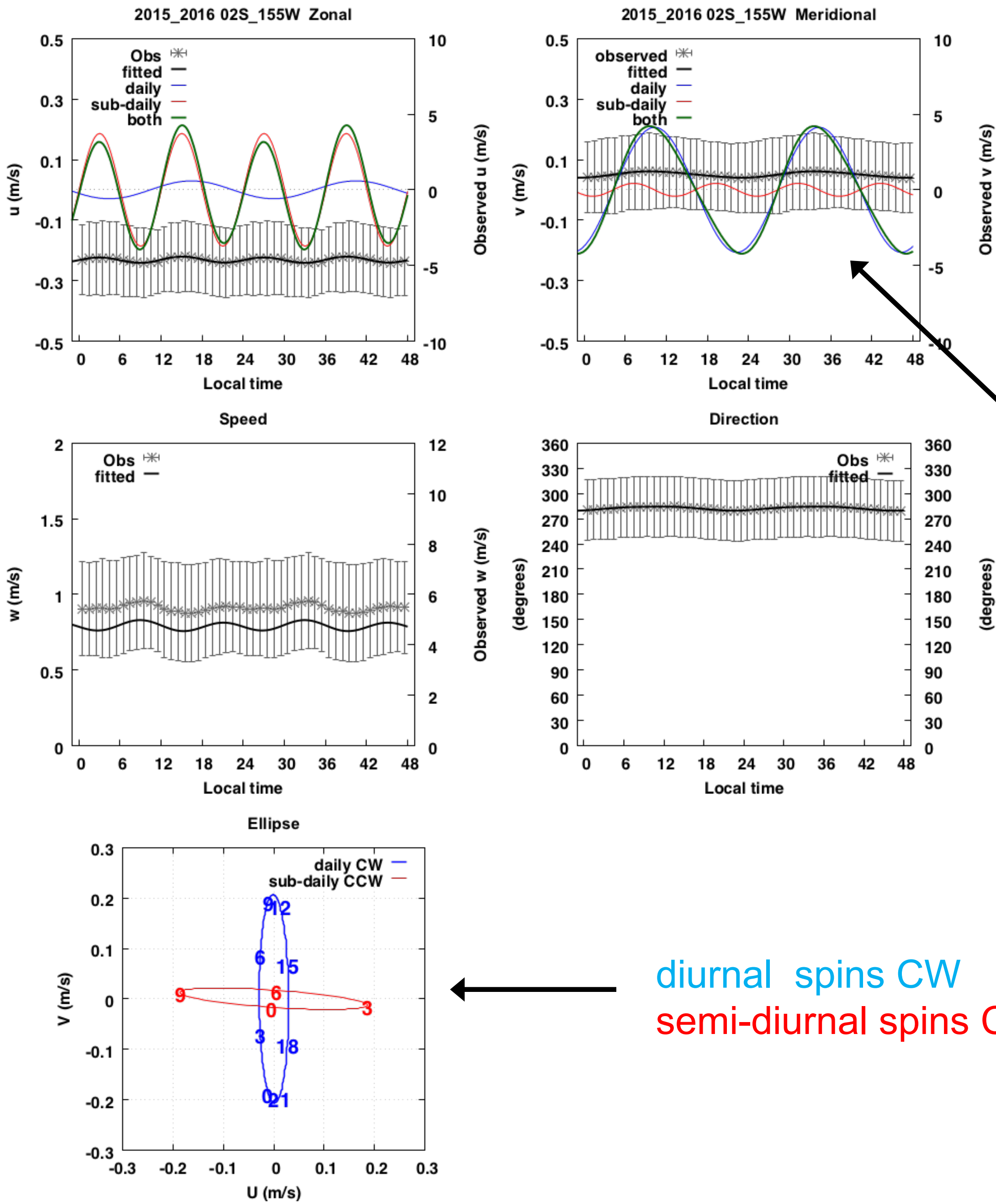
One analysis day from 16 May 2016 with RapidScat, 2 ASCAT, 2 WindSat, 2 AMSR-2 (n=7). Both the **diurnal (blue)** and a smaller **sub-diurnal (red)** wind ellipse spin CW with magnitudes < 3 m s^{-1}.





Offshore of Colombia coast

Each line is one of the days where R^2 values exceeded 0.9 during 2003-2016, all scatterometers and radiometers (scat+rad)



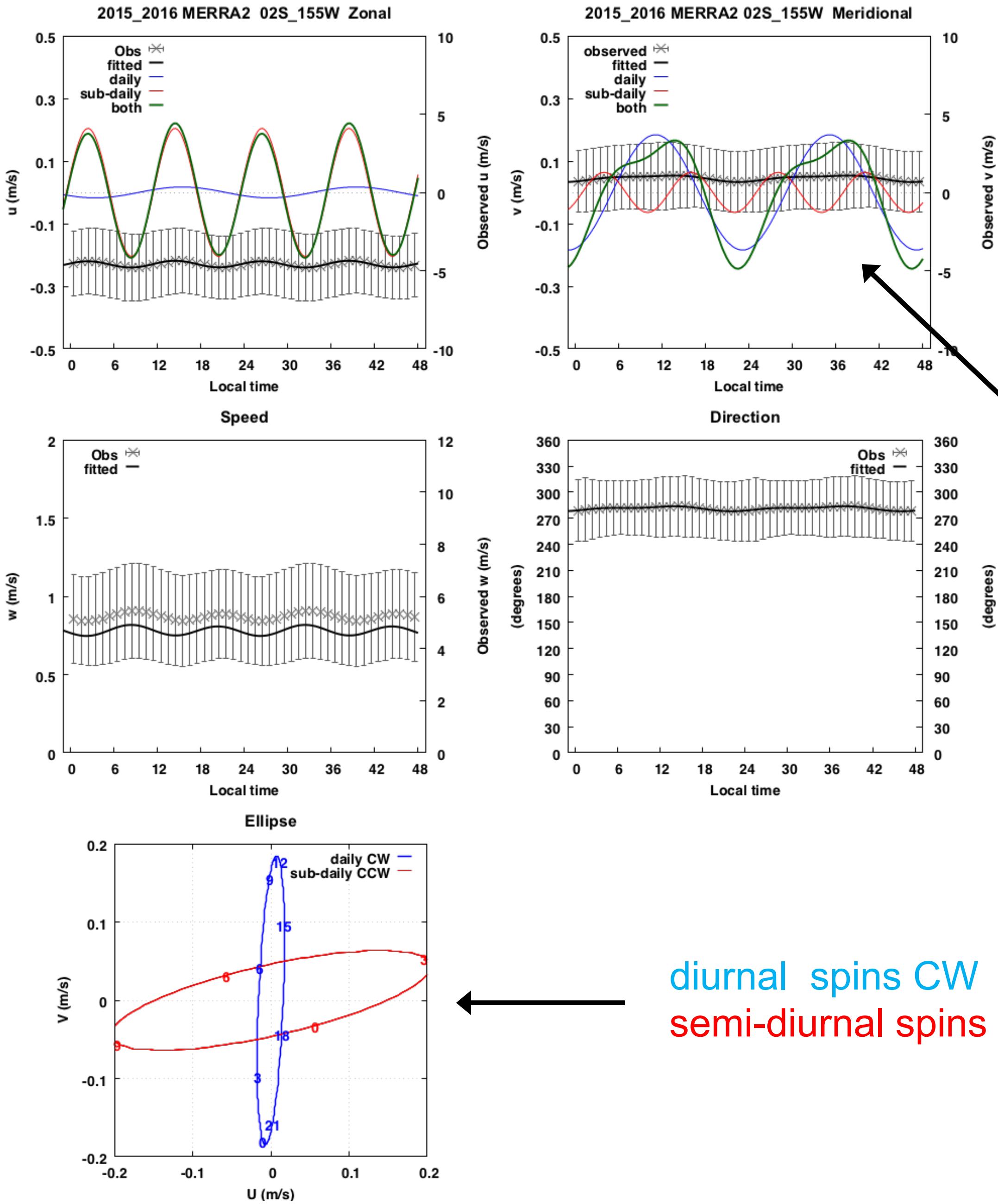
2015

2S 155W

TAO/TRITON (10-min data averaged to hourly

diurnal
semi-diurnal
diurnal + semi-diurnal

diurnal spins CW
semi-diurnal spins CCW



2015

2S 155W

MERRA2 (1-hr asm)

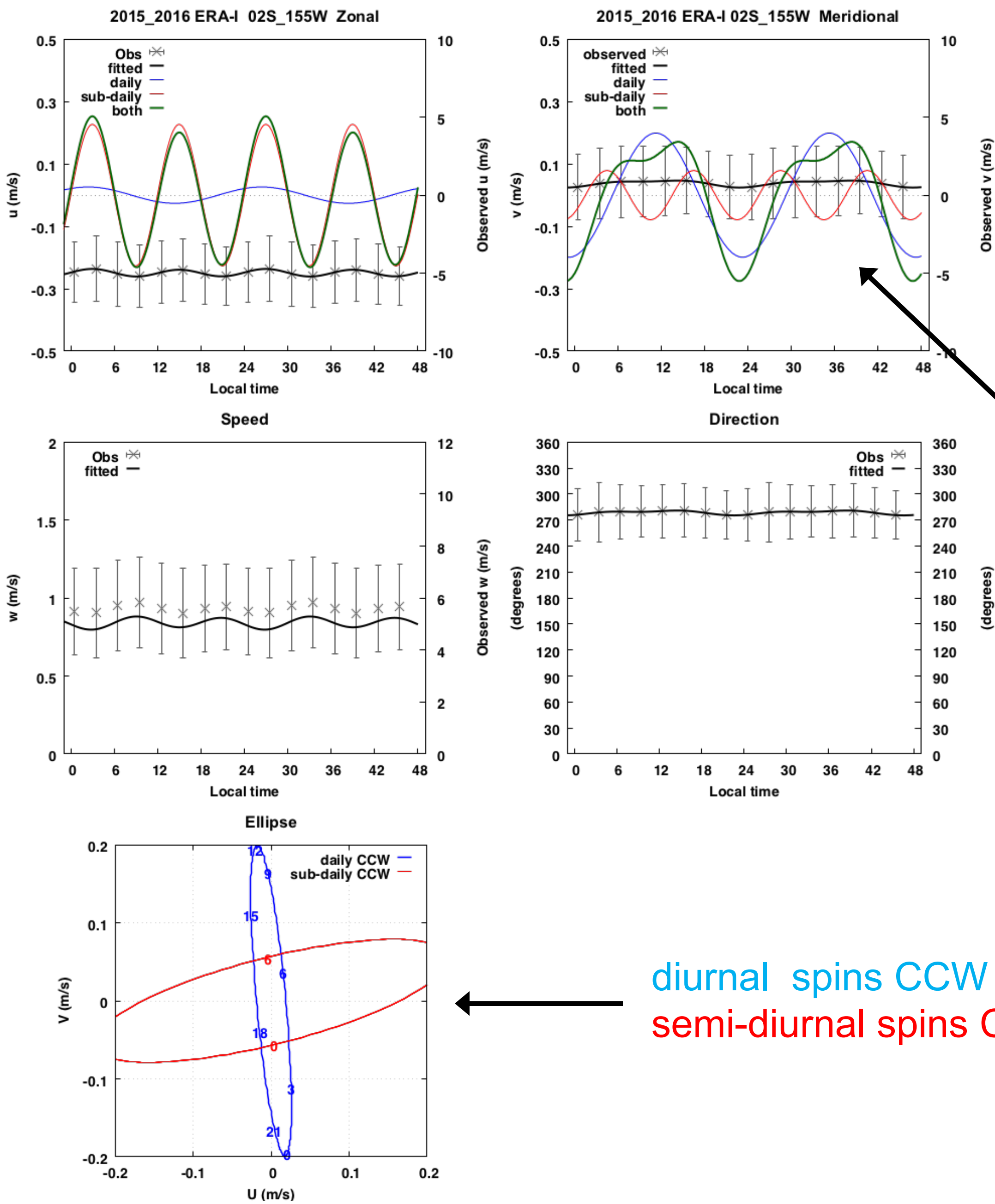
diurnal

semi-diurnal

diurnal + semi-diurnal

diurnal spins CW

semi-diurnal spins CCW



2015

2S 155W

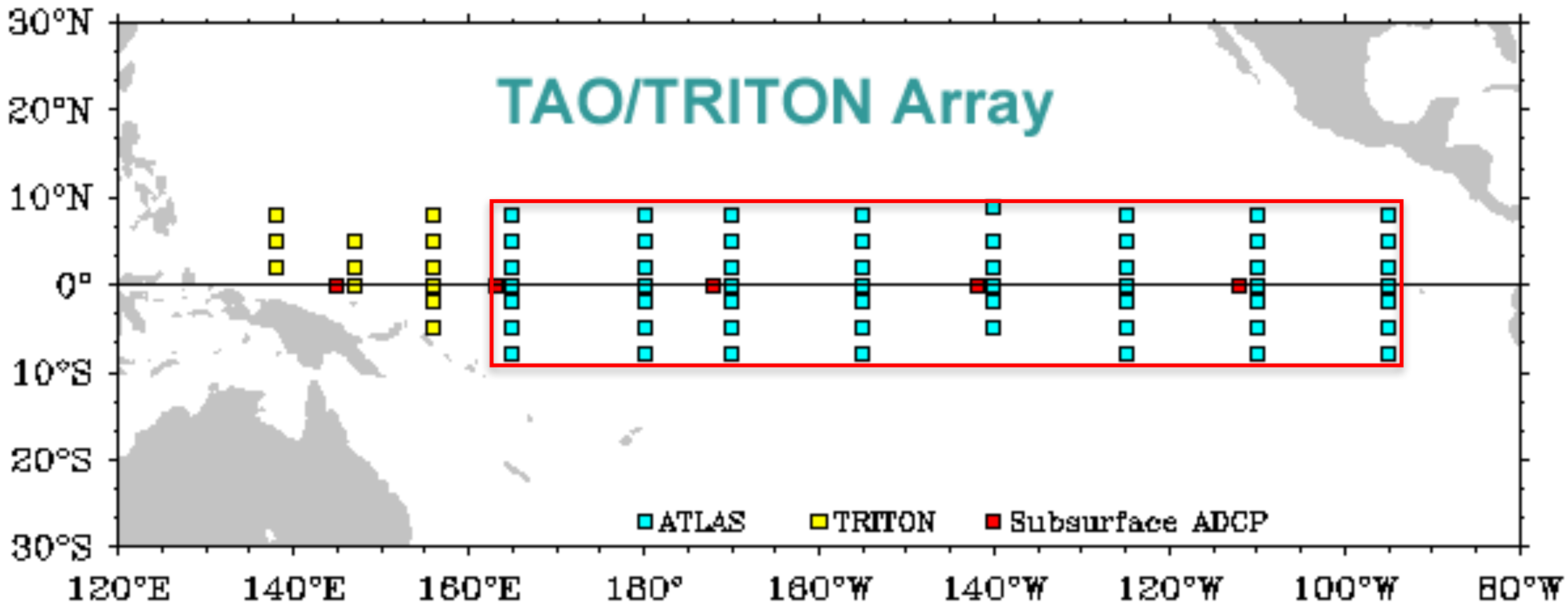
ERA-I (3-hourly)

diurnal
semi-diurnal
diurnal + semi-diurnal

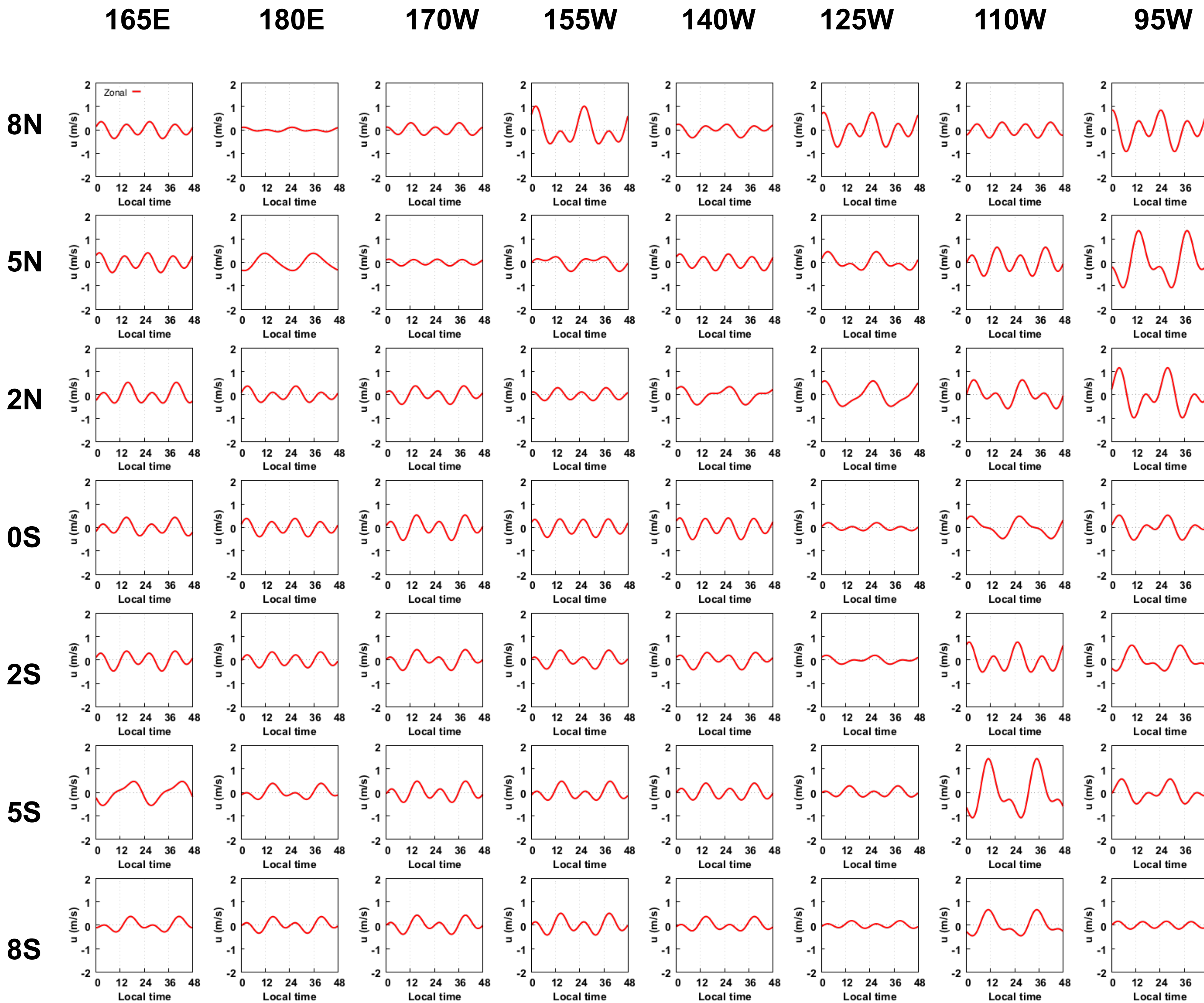
In general, the models agree with the moorings in speed in direction, but less so in daily variability (not the best example shown)

diurnal spins CCW
semi-diurnal spins CCW

Compare daily wind harmonic components estimated for all scatterometer + radiometer observations within a surrounding 1-degree box at TAO/TRITON array locations



Scat+Rad
Zonal



Averaged over all 2007-2016

Mostly semi-diurnal

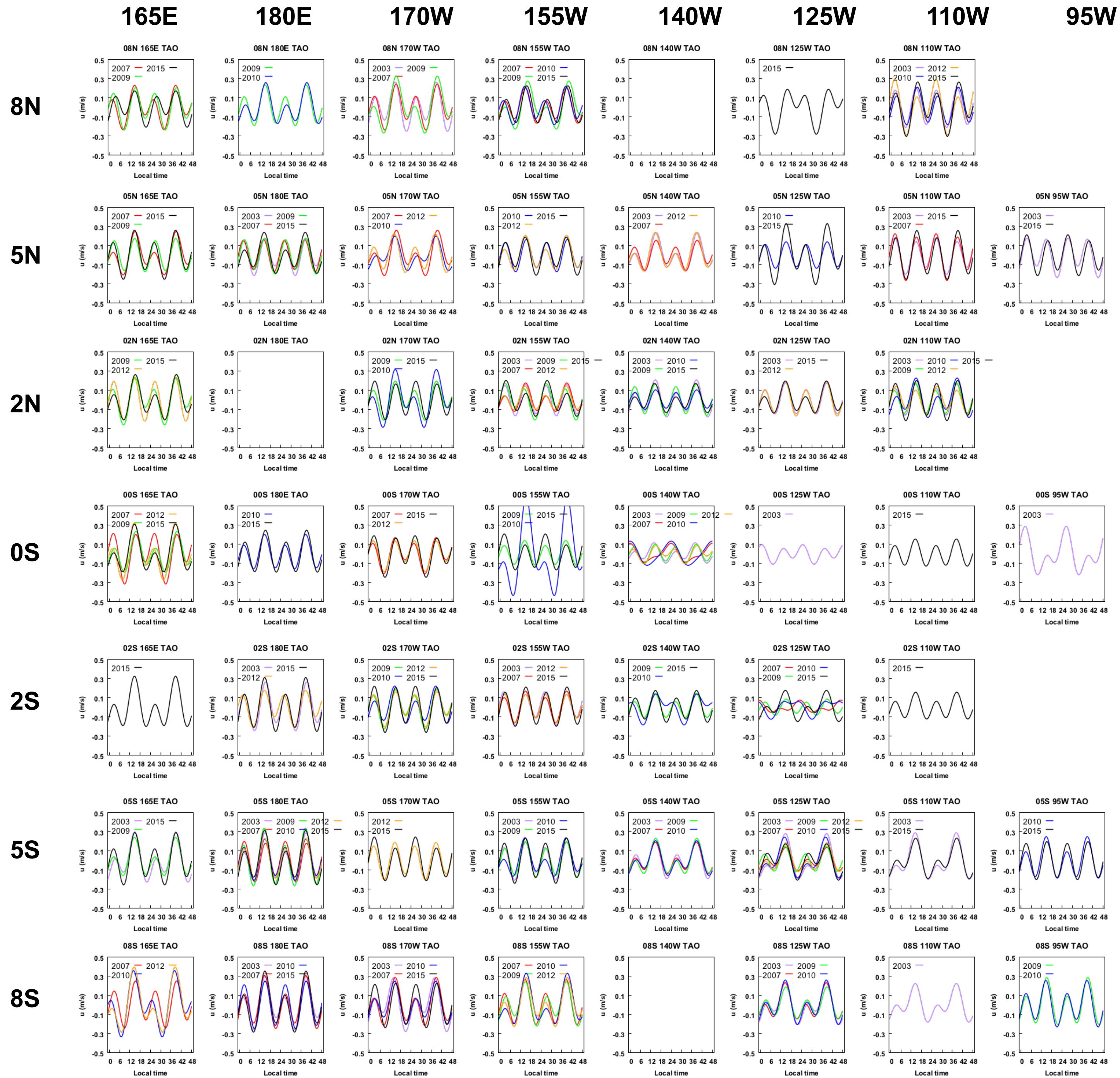
Each panel:

x-axis extends 0-48 hr local

y-axis extends $\pm$2 m/s

TAO zonal

2003
2007
2009
2010
2012
2015



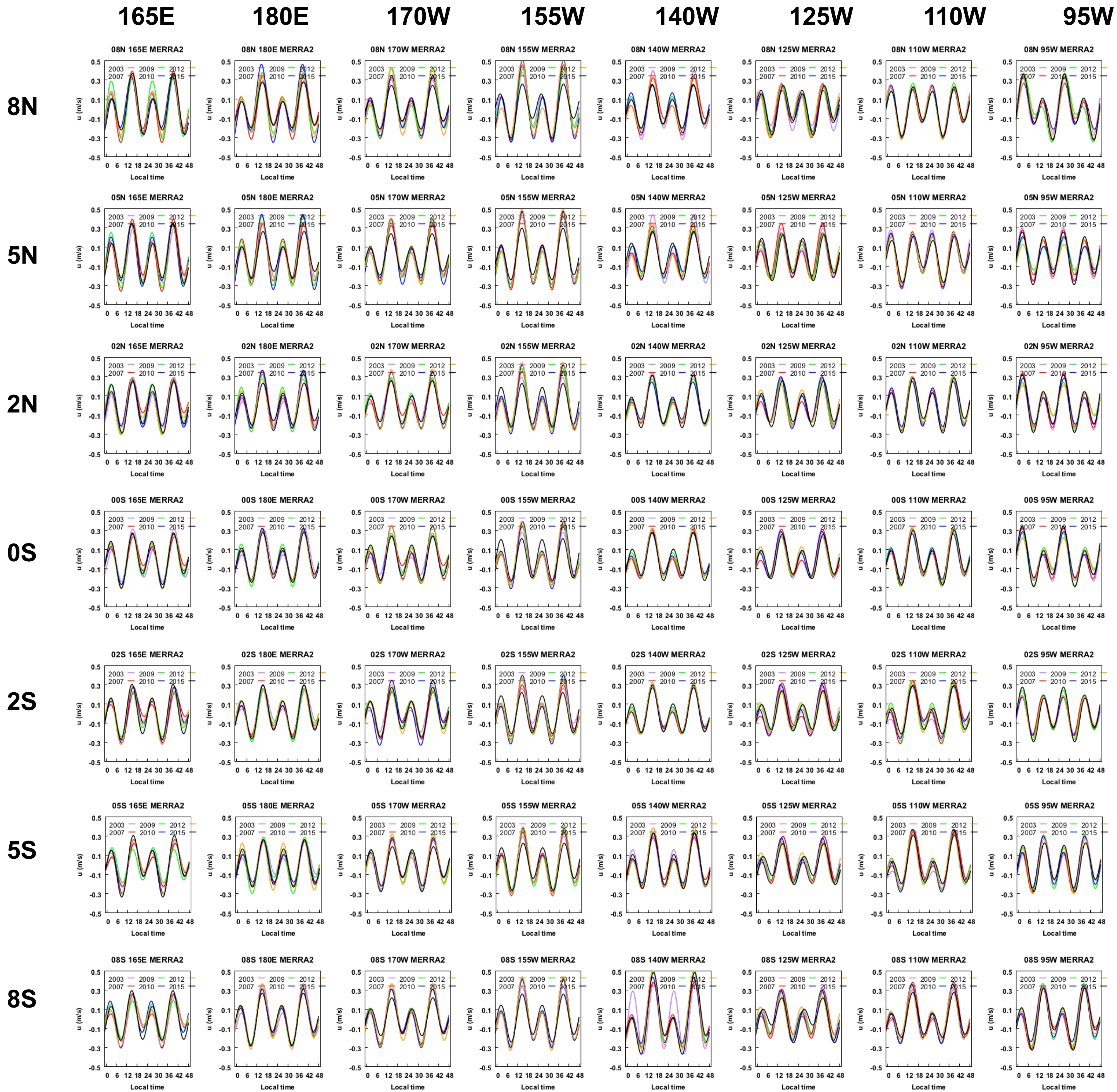
Each panel:

x-axis extends 0-48 hr local

y-axis extends ±0.5 m/s

MERRA2 zonal

2003
2007
2009
2010
2012
2015



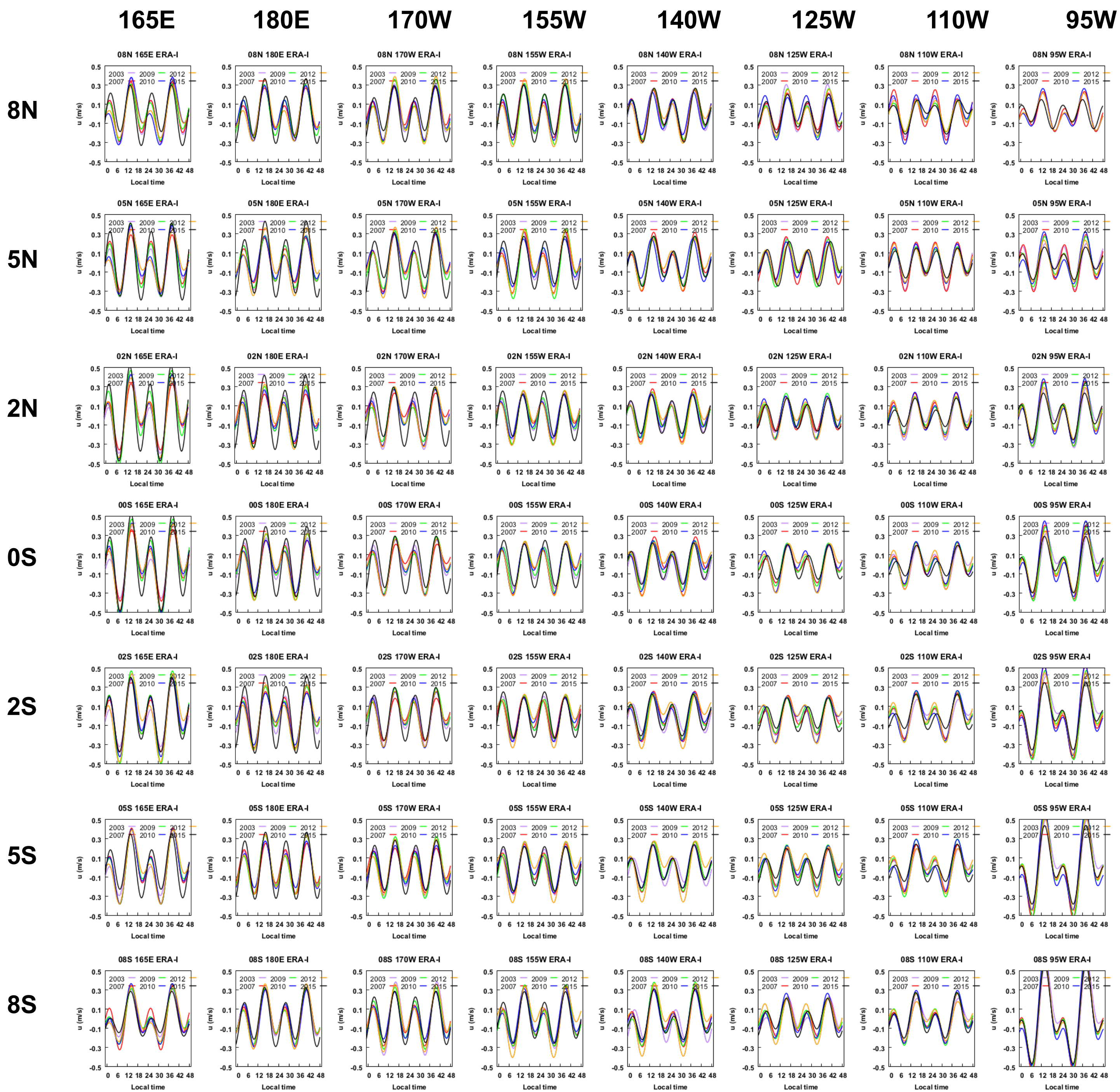
Each panel:

x-axis extends 0-48 hr local

y-axis extends ±0.5 m/s

ERA-I zonal

2003
2007
2009
2010
2012
2015



Each panel:

x-axis extends 0-48 hr local

y-axis extends ±0.5 m/s

Scat+Rad Meridional

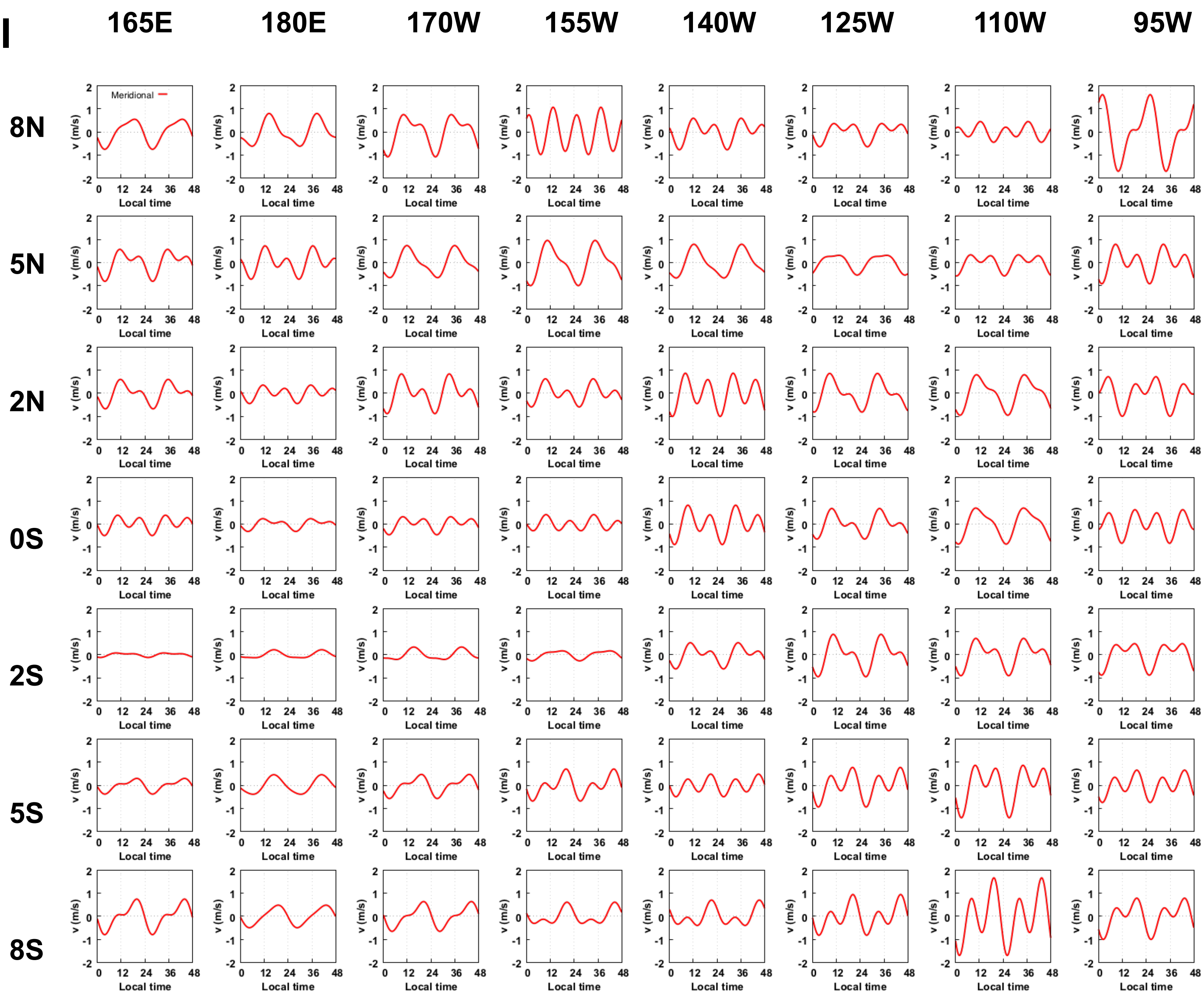
Averaged over all 2007-2016

Mostly diurnal, but less in agreement with moorings

Each panel:

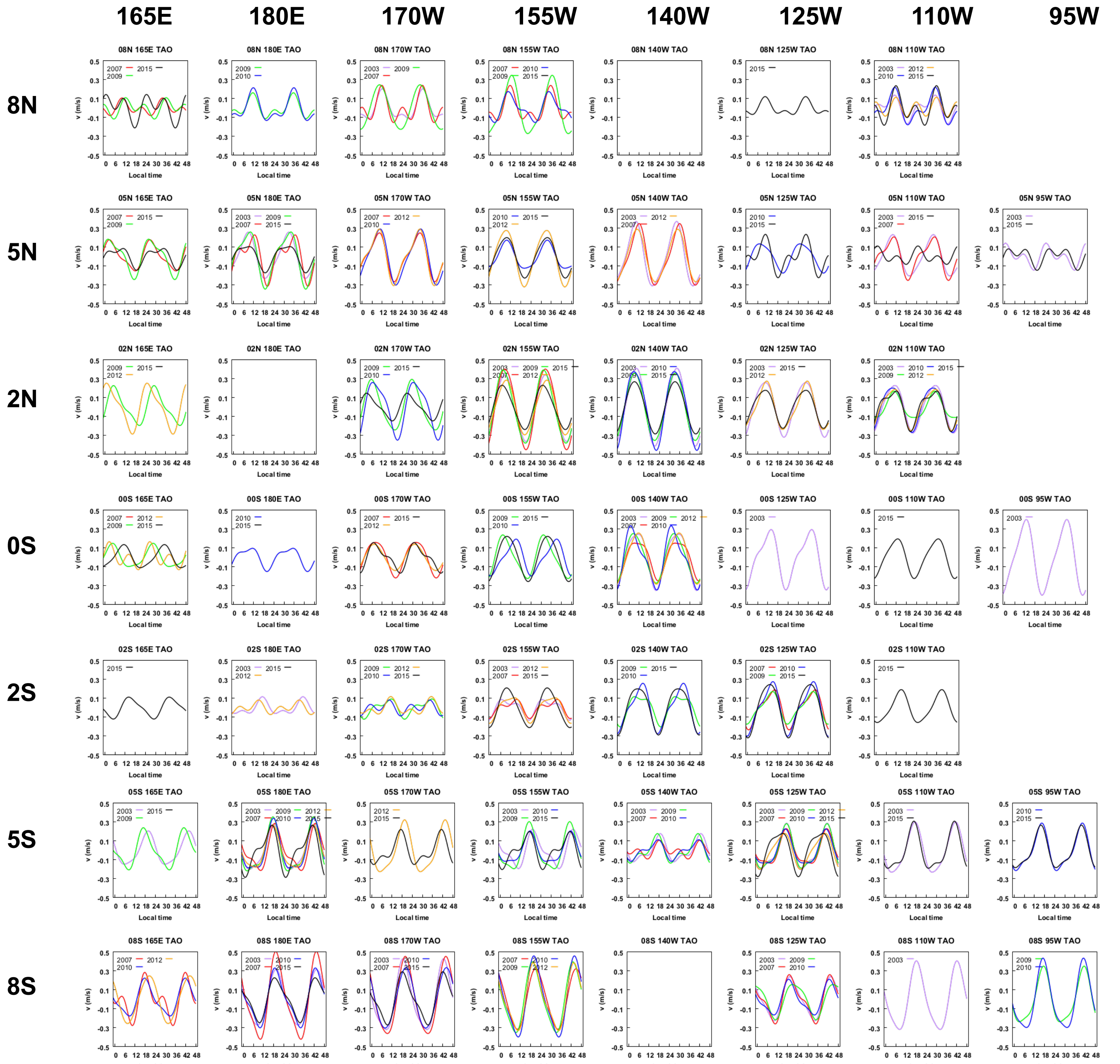
x-axis extends 0-48 hr local

y-axis extends ±2 m/s



TAO meridional

2003
2007
2009
2010
2012
2015



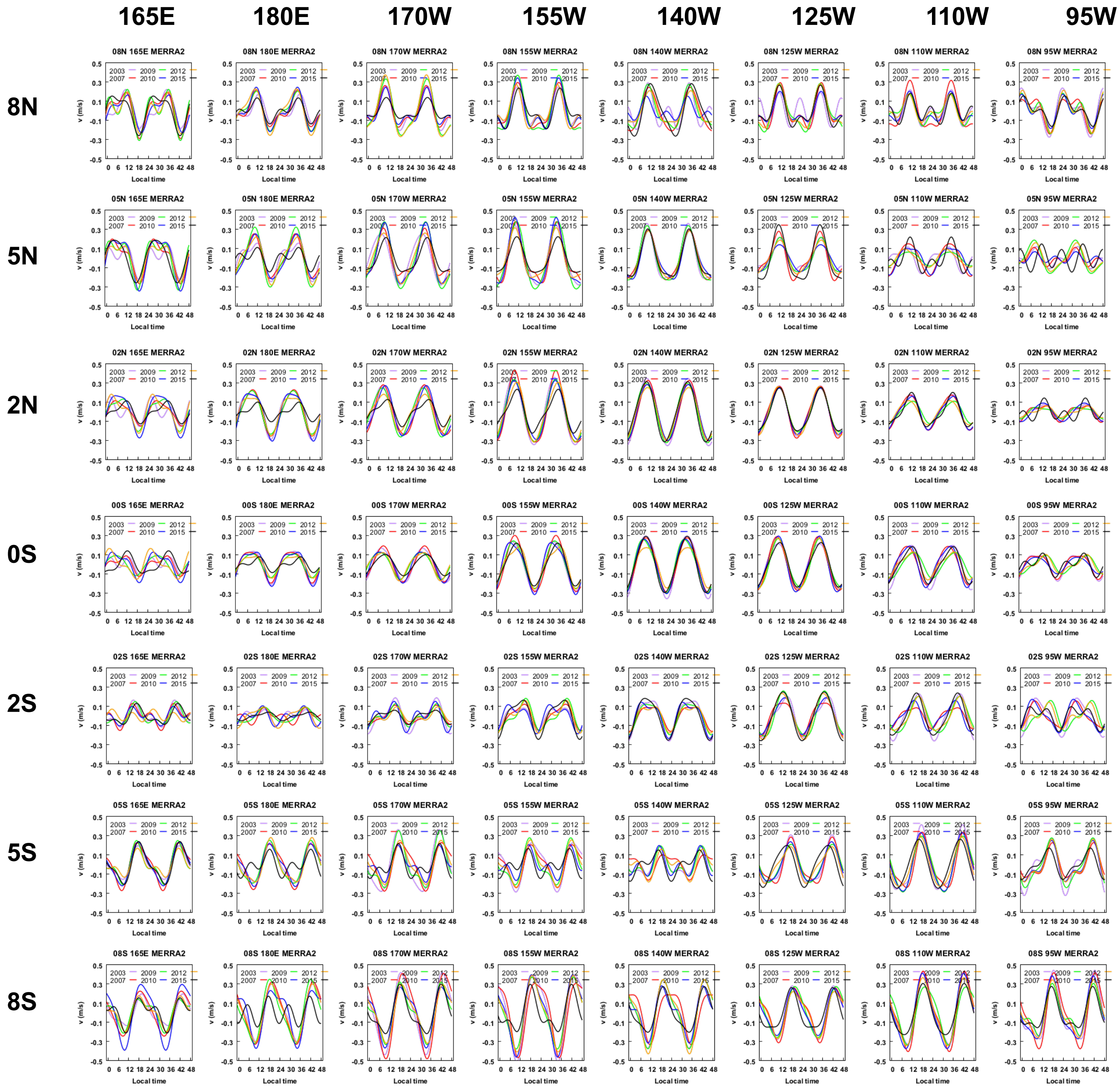
Each panel:

x-axis extends 0-48 hr local

y-axis extends ±0.5 m/s

MERRA2 meridional

2003
2007
2009
2010
2012
2015



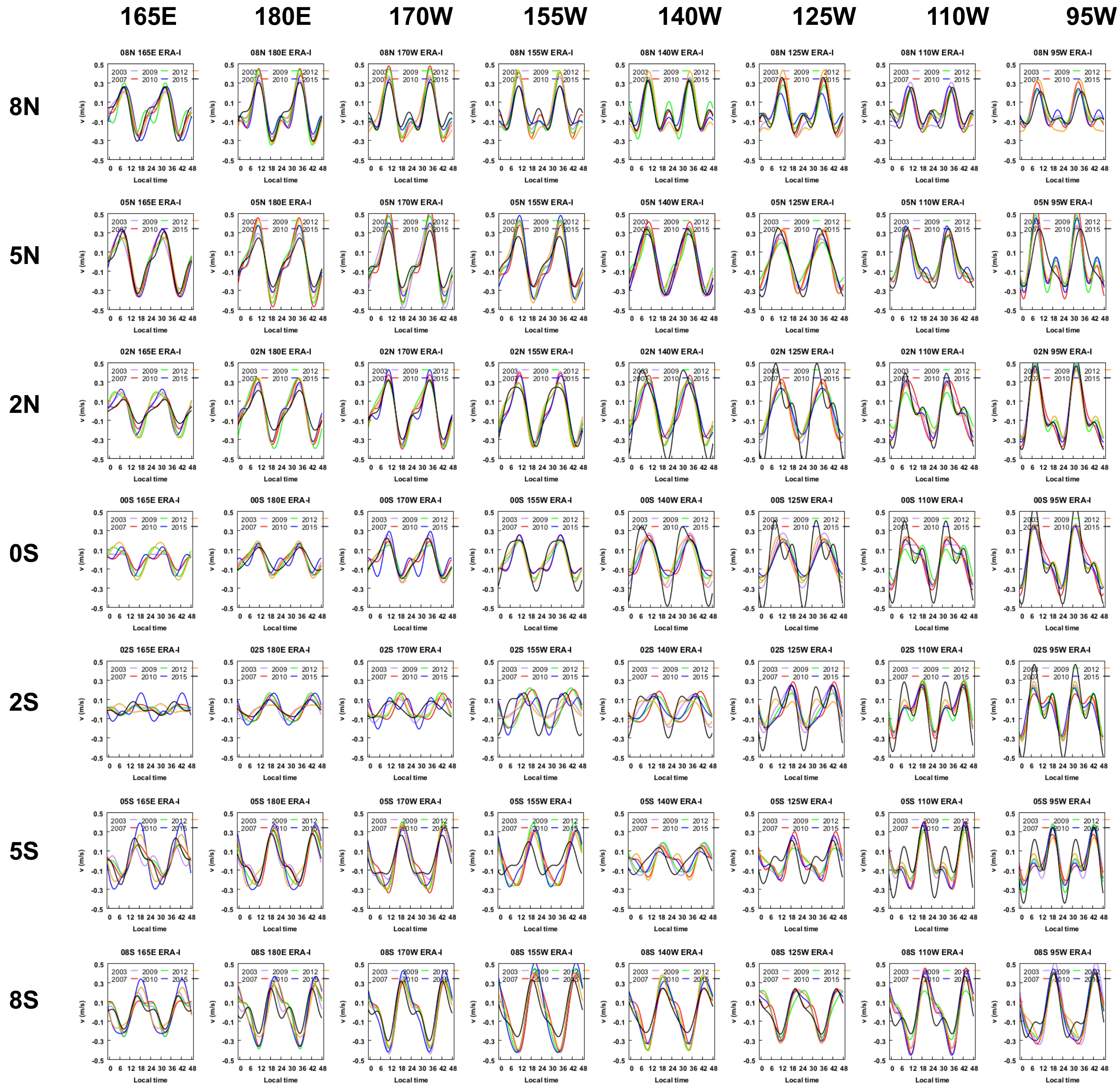
Each panel:

x-axis extends 0-48 hr local

y-axis extends ±0.5 m/s

ERA-I meridional

2003
2007
2009
2010
2012
2015

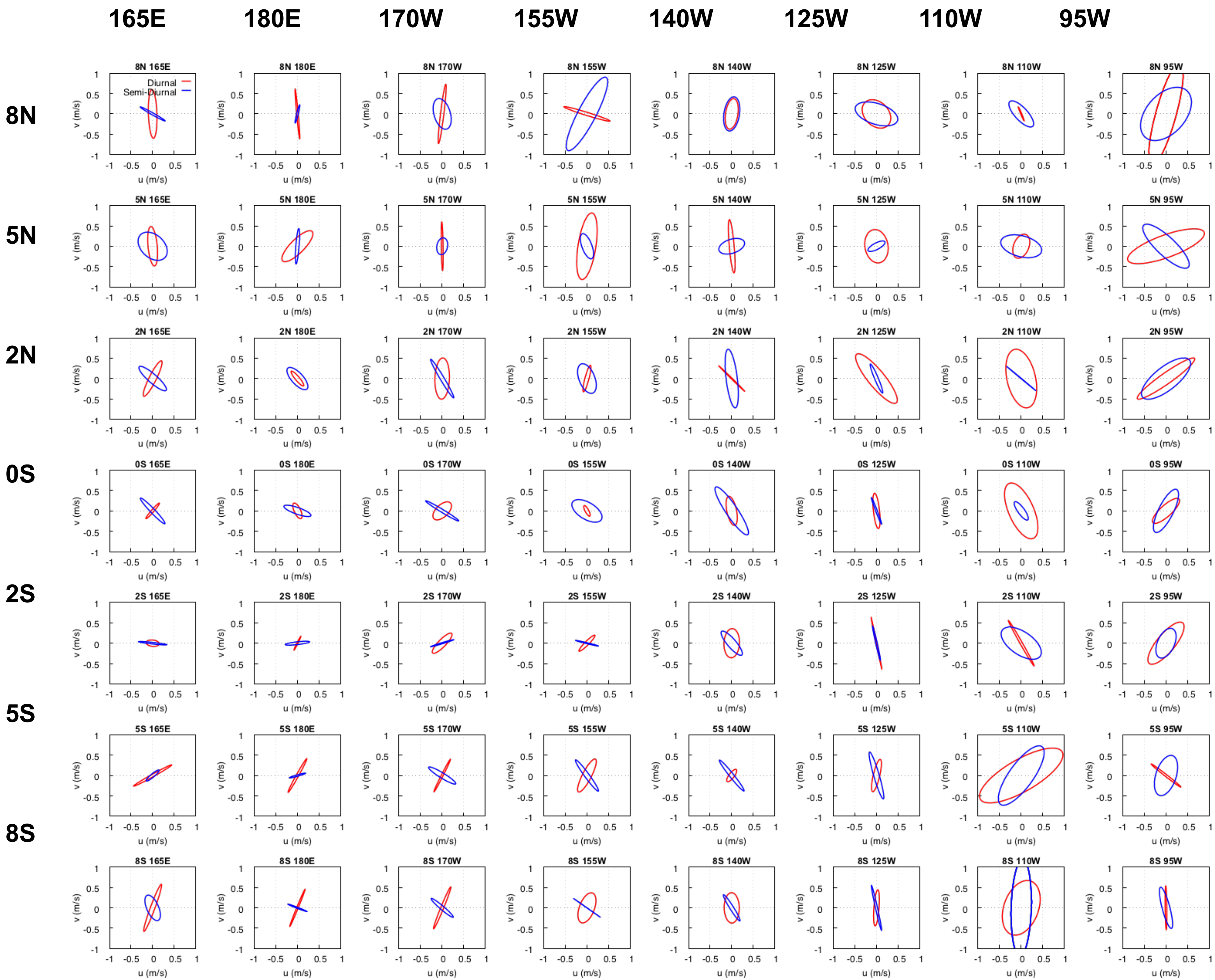


Each panel:

x-axis extends 0-48 hr local

y-axis extends ±0.5 m/s

Scat+Rad ellipses



Each panel:

Diurnal
Semi-diurnal

Both x- and y-axis extends ±1 m/s

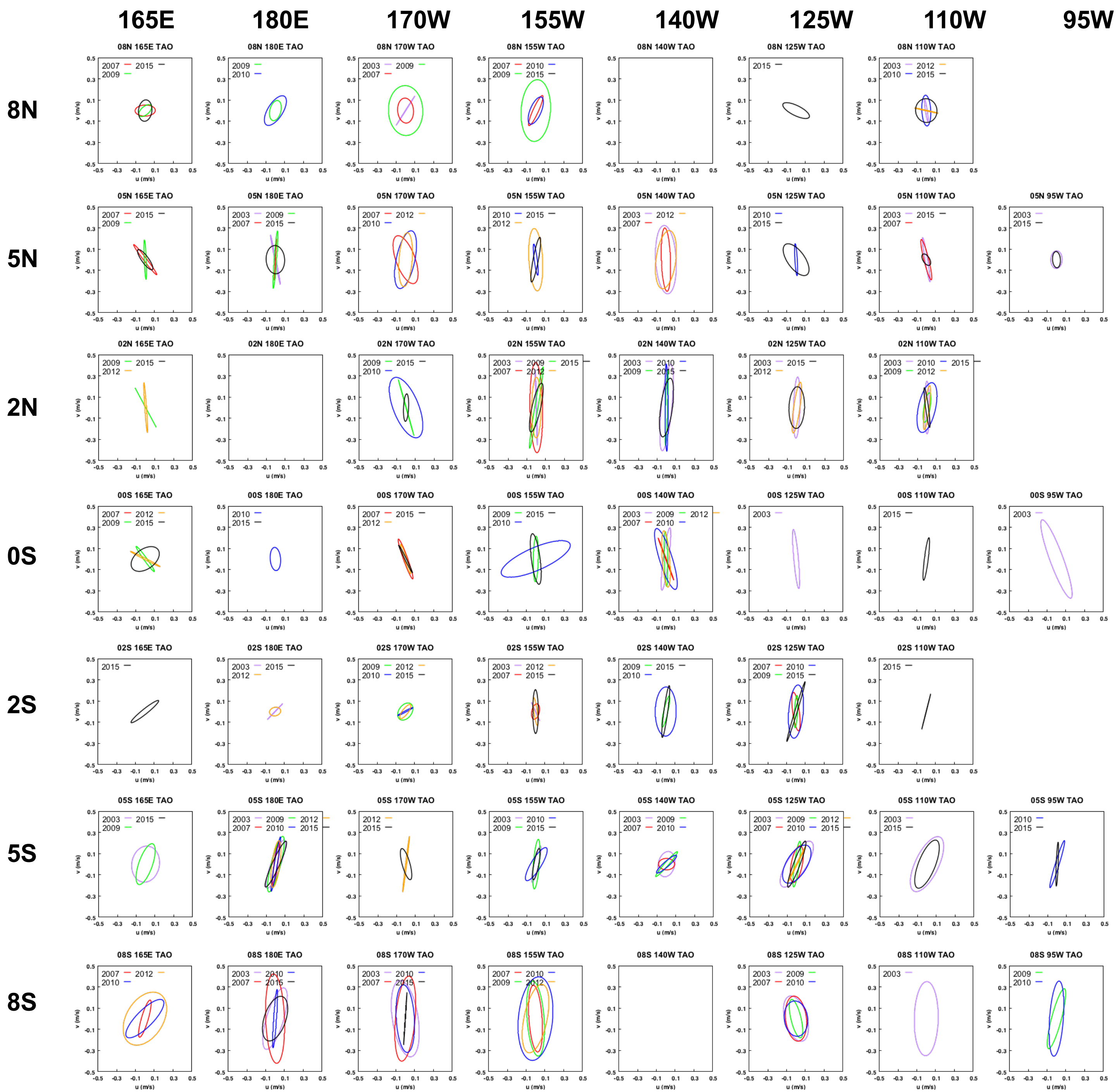
TAO ellipses

2003
2007
2009
2010
2012
2015

Each panel:

diurnal only

Both x- and y-axis extends ±0.5 m/s



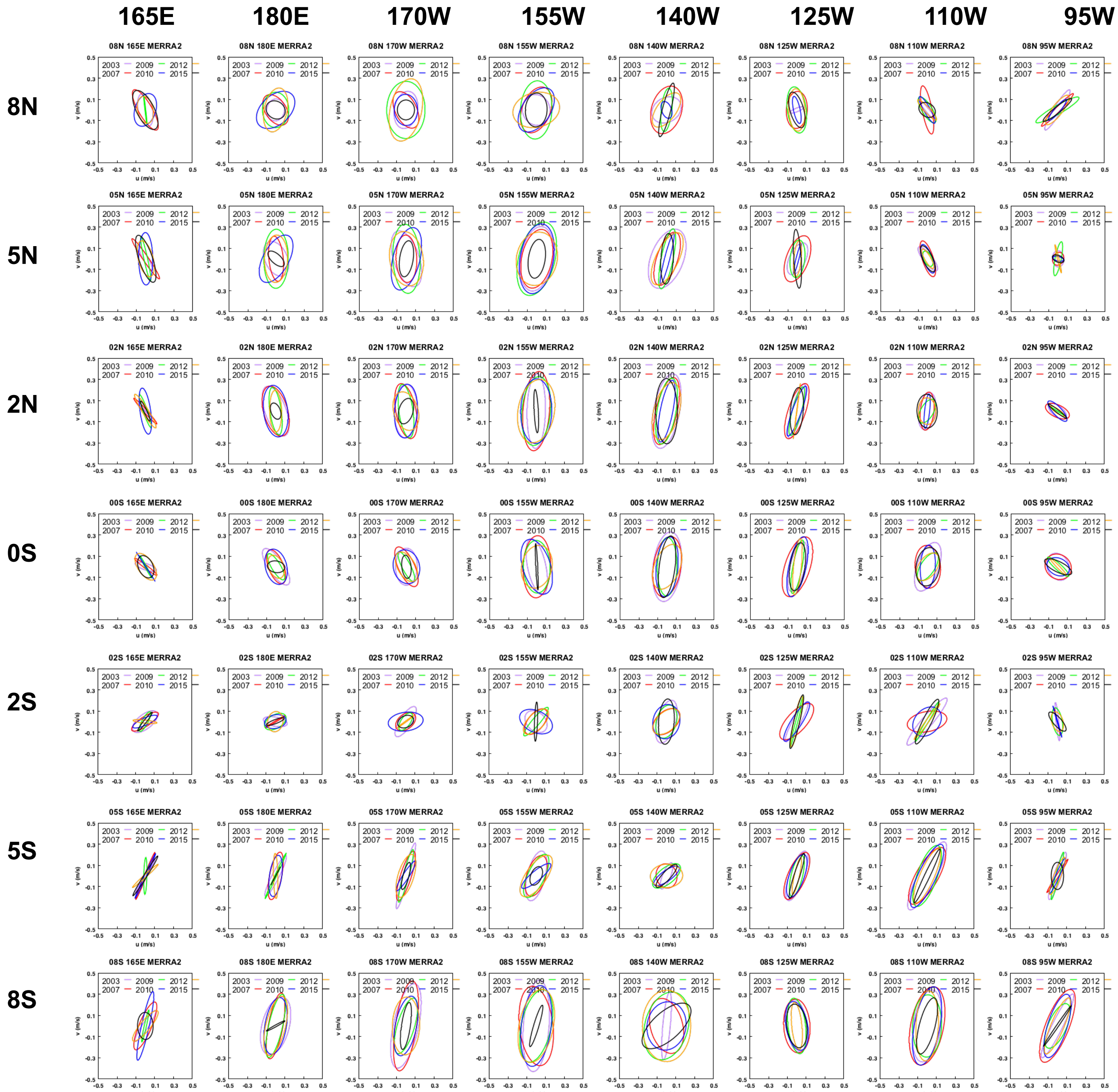
MERRA2 ellipses

2003
2007
2009
2010
2012
2015

Each panel:

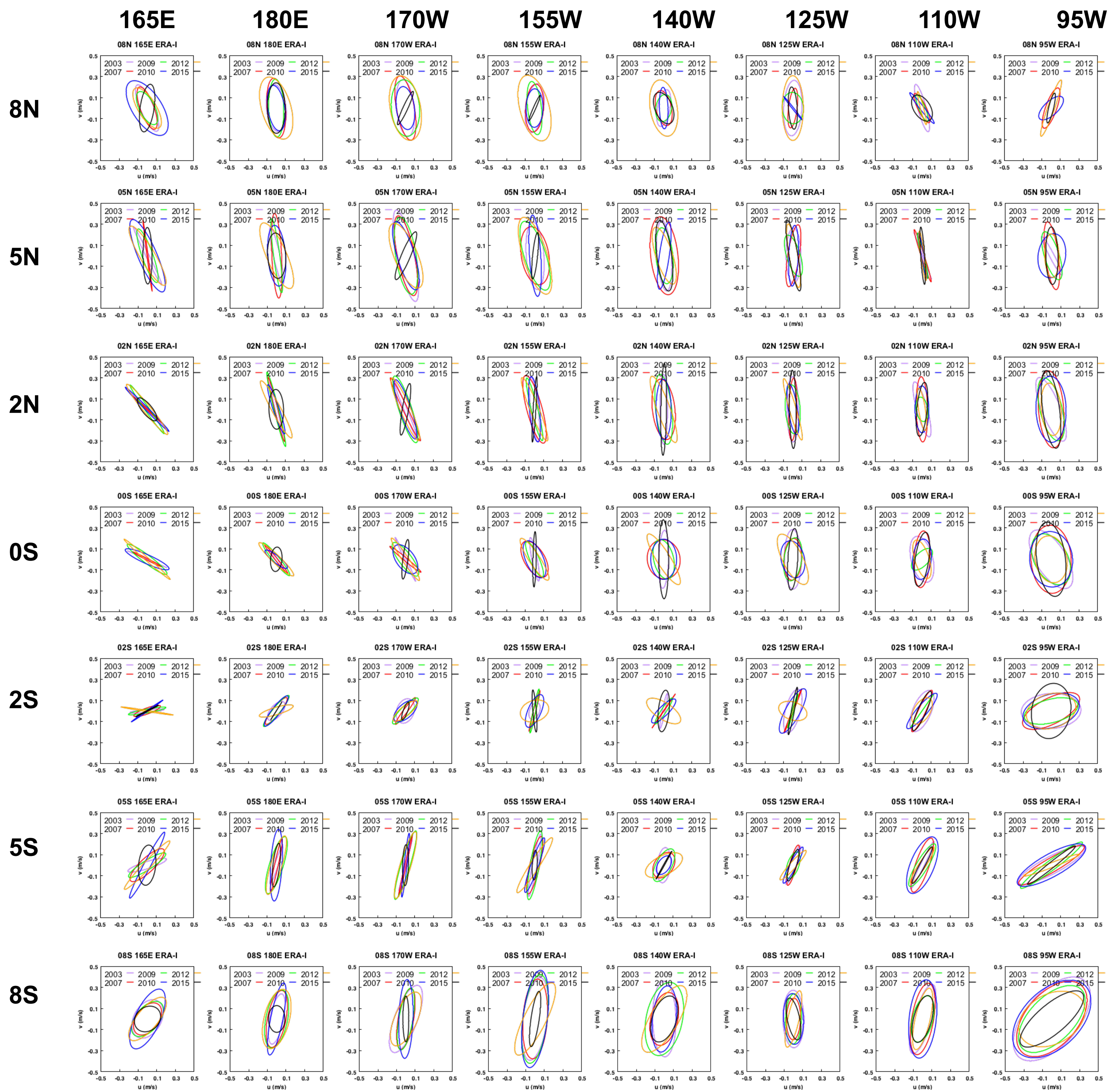
diurnal only

Both x- and y-axis extends ±0.5 m/s



ERA-I ellipses

2003
2007
2009
2010
2012
2015



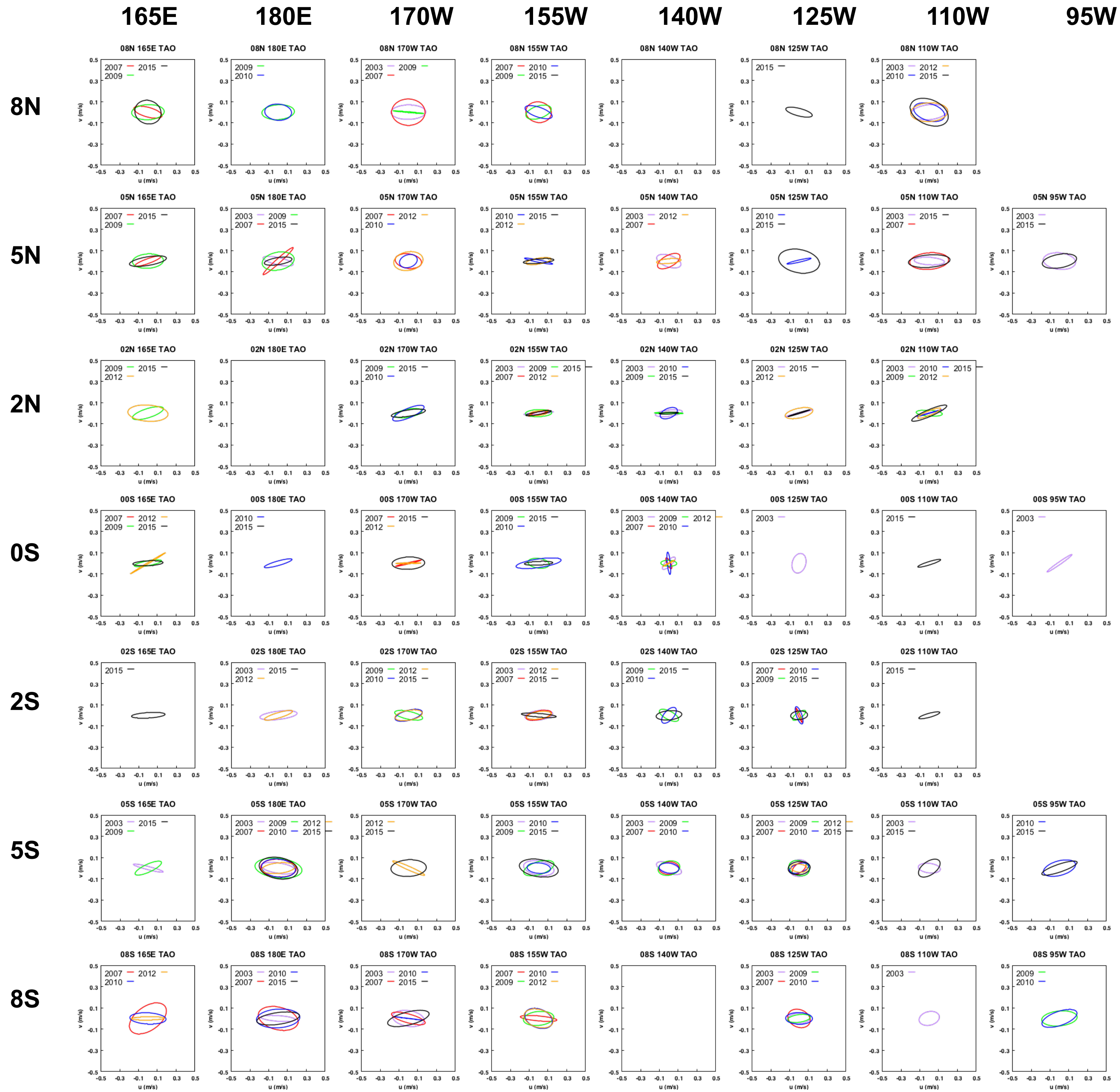
Each panel:

diurnal only

Both x- and y-axis extends ±0.5 m/s

TAO ellipses

2003
2007
2009
2010
2012
2015



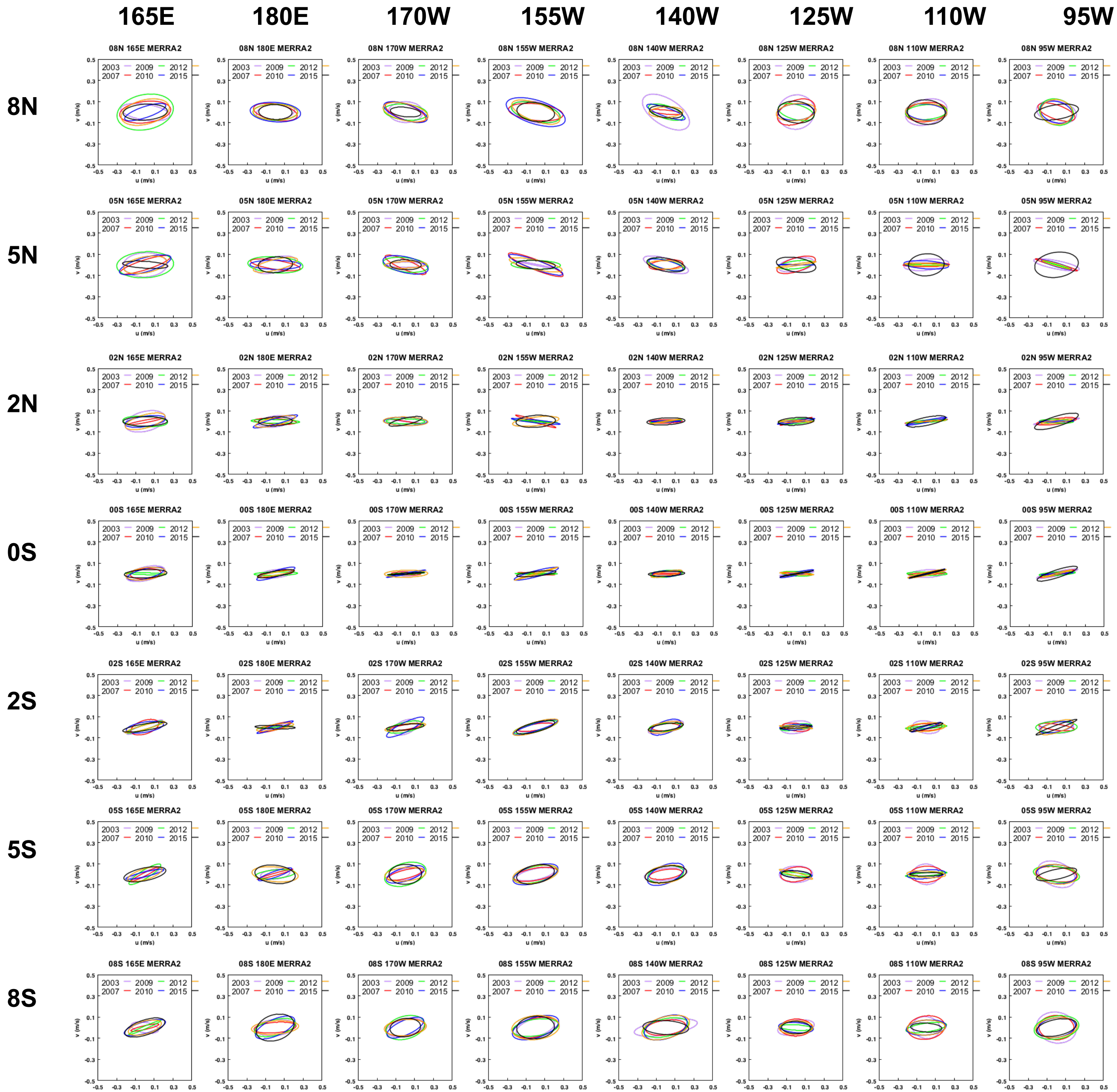
Each panel:

semi-diurnal only

Both x- and y-axis extends ±0.5 m/s

MERRA2 ellipses

2003
2007
2009
2010
2012
2015



Each panel:

semi-diurnal only

Both x- and y-axis extends ±0.5 m/s

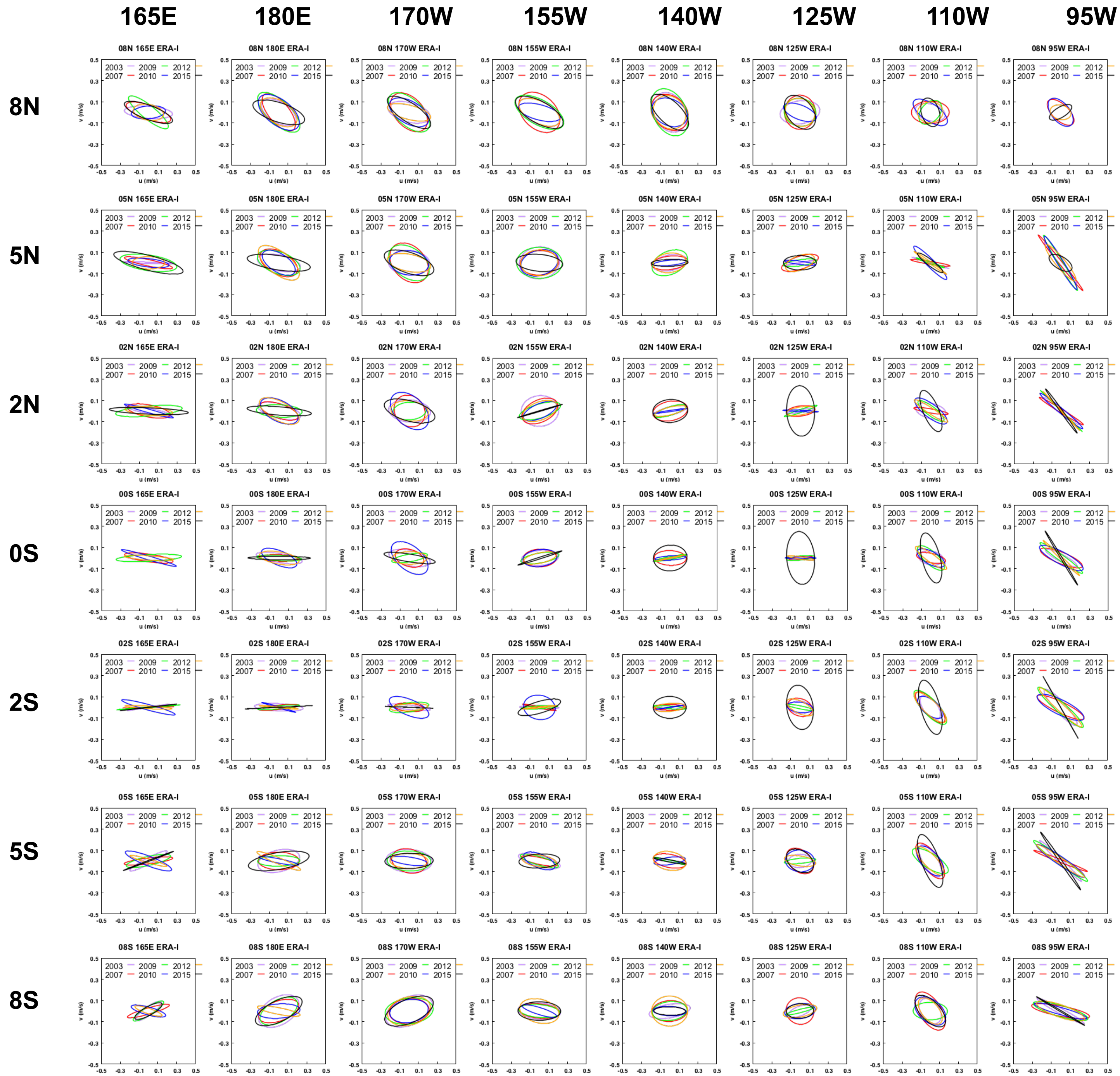
ERA-I ellipses

2003
2007
2009
2010
2012
2015

Each panel:

semi-diurnal only

Both x- and y-axis extends ±0.5 m/s



Ocean Winds and Atmospheric Processes

Surface winds are coupled to winds above; diurnal winds coupled to diurnal precipitation

The mechanisms linking convection and cloud *dynamical* processes is a major factor in much of the uncertainty in both weather and climate prediction.

Further constraining the uncertainty in convective cloud processes linking 3-D air motion and cloud structure through models and observations is vital for improvements in weather forecasting and understanding limits on atmospheric predictability.

NASA's Convective Processes Experiment (CPEX) in May-June 2017, (based out of Ft Lauderdale), 100 DC-8 flight hours

Capture developing oceanic convection with JPL Ku/Ka-band APR-2 radar, and enough nearby "clear air" to capture 3-D wind structure from a Doppler wind lidar (DAWN)


ARMSTRONG FLIGHT RESEARCH CENTER

Summary

In general the longterm scat+rad daily wind data record captures the semi-diurnal zonal wind noted by the moorings and models, but with a larger amplitude

Less so for the meridional wind, where year to year differences between models themselves and scat+rad appear more noticeable

Suggests a broader look at between the ocean surface diurnal (and semi-diurnal, where possible) winds and the long-term year-to-year differences in the diurnal precipitation record from TRMM/GPM (away from continents)

Focus on vertical structure

More thought put into proper matching framework amongst models, satellite winds, moorings before drawing any conclusions